

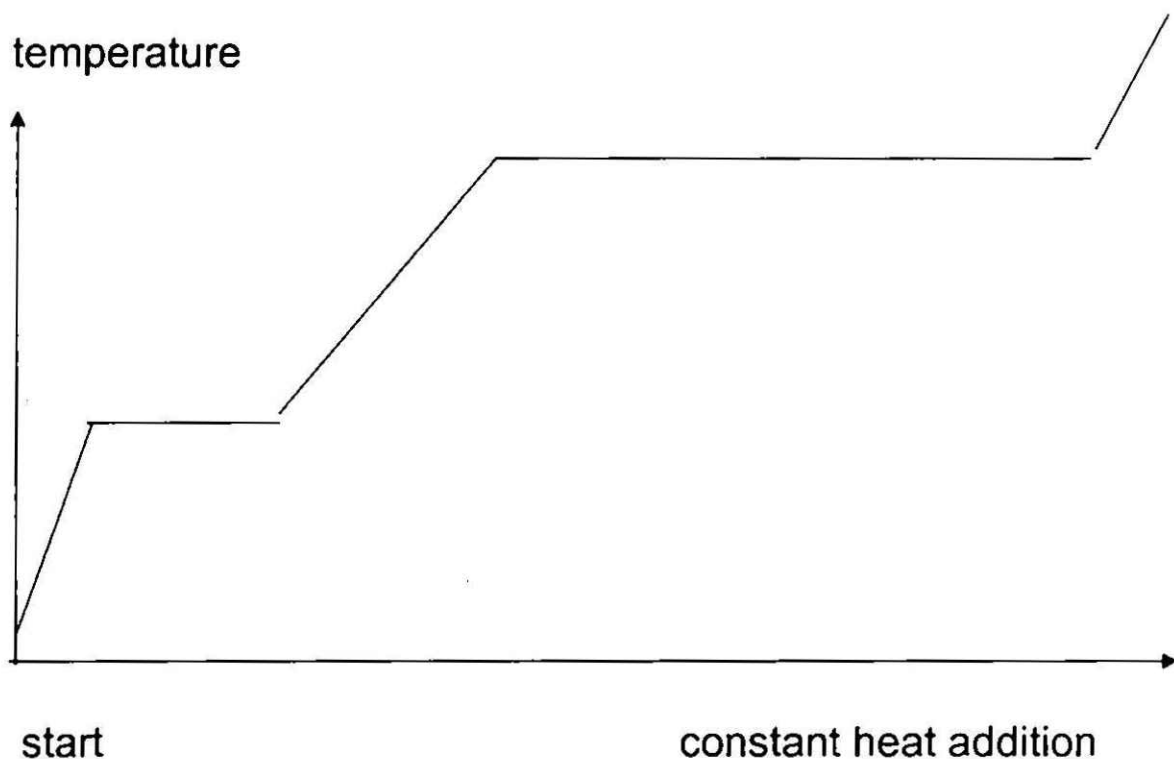
Major Points for Chapter 17 THERMOCHEMISTRY

NOTE: Be sure to read the vocabulary for each section which are written in the book's margins.

1. Convert between units of energy.
2. Be sure that you can use the specific heat algorithm
 $C = q / (m \times \Delta T)$ in an elegant, formula-method solution.
3. Relate heat to enthalpy.
4. Perform calorimetry problems.
5. Interpret thermochemical equations.
6. Understand and solve for molar heat of combustion, fusion, etc.
7. How does a heating curve show energy changes for a pure substance?
8. Use Hess's Law to calculate complex heats of reaction.
9. Calculate heat of reaction from standard heats of formation.

HEATING CURVE FOR A PURE SUBSTANCE

temperature vs constant heating



7. Do # 12, 14 on page 513 and 516.

8. Why are the heat of fusion/solidification and vaporization/condensation equal and opposite quantities for a given substance?

9. Do # 26 on page 526.

10. In what scenario would you use Hess's law or standard heats of formation to calculate the heat change for a reaction?

11. Do # 32 on page 531.

Written Work

Write answers to the above objectives and answer these questions:

p. 535-538 # 43, 46, 47, 50, 54, 55, 56, 59, 62, 63, 65, 66, 67, 69-75, 78, 81-85,
89, 94, 96, 100, 102

p. 539 # 2-14 even

Phase Change Worksheet – Answer Sheet

- 1) A 12 oz. can of soda weighs about 450 grams. How many joules are released when a can of soda is cooled from 25 degrees Celsius (room temperature) to 4 degrees Celsius (the temperature of a refrigerator). **The heat capacity of liquid water is $4.18 \text{ J / gram} \times ^\circ\text{C}$.** ~~39.5 kJ~~ **40. kJ**
- 2) How many joules are required to heat 250 grams of liquid water from 0°C to 100°C ? **104.5 kJ**
- 3) How many joules are required to melt 100 grams of water? **The heat of fusion of water is 6.01 kJ / mole .** **33.4 kJ**
- 4) How many joules are required to boil 150 grams of water? **The heat of vaporization of water is 40.67 kJ / mole .** **338.8 kJ**
- 5) How many joules are required to heat 200 grams of water from 25°C to 125°C ? **The heat capacity of steam is $1.84 \text{ J / g} \cdot ^\circ\text{C}$** **523.9 kJ**
- 6) How many joules are given off when 120 grams of water are cooled from 25°C to -25°C ? **The heat capacity of ice is $2.09 \text{ J / g} \cdot ^\circ\text{C}$.** **63.9 kJ** ~~63.8 kJ~~
- 7) How many joules are required to heat 75 grams of water from -85°C to 185°C ? **The heat capacity of steam is $1.84 \text{ J / g} \cdot ^\circ\text{C}$.** **250.9 kJ**
- 8) How many joules are required to heat a frozen can of juice (360 grams) from -5°C (the temperature of an overcooled refrigerator) to 110°C (the highest practical temperature within a microwave oven)? **1094.46 kJ**
- 9) How many joules are released when 450 grams of water are cooled from $4 \times 10^7^\circ\text{C}$ (the hottest temperature ever achieved by man) to $1 \times 10^{-9}^\circ\text{C}$ (the coldest temperature achieved by man). **$3.31 \times 10^{10} \text{ J}$**
- 10) How many joules are required to raise the temperature of 100 grams of water from -269°C (the current temperature of space) to $1.6 \times 10^{15}^\circ\text{C}$ (the estimated temperature of space immediately after the big bang)? **$2.94 \times 10^{17} \text{ J}$**

Thermodynamics Worksheet

Fill the blanks in the following sentences with the correct thermodynamics term:

- 1) A(n) _____ is used to lower the energy required to make a reaction take place. It makes chemical reactions go faster without being consumed.
- 2) Another word for freezing is _____.
- 3) The thing we measure when we want to determine the average kinetic energy of random motion in the particles of a substance is _____.
- 4) The _____ is the energy needed to raise the temperature of a substance by one degree Celsius.
- 5) A(n) _____ reaction is one where the products have lower energy than the reactants.
- 6) _____ reactions require energy in order to take place.
- 7) _____ changes take place by themselves, without any help.
- 8) The _____ is the energy required to boil one mole of a substance, and its symbol is _____.
- 9) _____ are the SI unit used to report heat values
- 10) The _____ is used to describe how much energy is produced or used during a chemical change.

Ch10

10.1- 10.3

1. Specific heat- The amount of energy required to heat one gram of a substance by one degree Celsius
2. Heat capacity- The amount of energy required to heat a substance by one degree Celsius- depends on the mass of the substance
3. Units of energy- Calories and joules, one joule equals .239 calories
4. Conservation of energy- In any chemical process, energy is neither created nor destroyed
5. Heat- a form of energy that ALWAYS flows from a warmer object to a cooler object

What is the specific heat of silicon if the temperature of a 4.11 g sample of silicon is increased by 3.8°C when 2.7 calories of heat is added?

A piece of stainless steel weighing 1.55g absorbs 141 joules of heat energy when its temperature increases by 178°C . What is the specific heat of stainless steel?

OBJECTIVE 2!!!

10.4 Exothermic and Endothermic Processes

System-the specific part of the universe on which you focus your attention (anything)

Surrounding-everything else outside the system

Endothermic Process-a process that absorbs heat from the surroundings

Exothermic Process-a process that loses heat to the surrounding

Heat Change Sign Conversion		
Direction of Heat Flow	Sign	Reaction Type
Heat flows out of the system	Heat change < 0 (negative)	Exothermic
Heat flows into the system	Heat change > 0 (positive)	Endothermic

10.5 Calorimetry

Calorimetry-the accurate and precise measurement of the heat change for chemical and physical processes

Enthalpy (H)-the heat content for systems at constant pressure

$$q = \Delta H = mC\Delta T$$

Practice Problems:

1. If I burn 120 grams propane in a calorimeter containing 5.0 liters of water, what's the molar heat of combustion of propane if the water temperature rises 30 degrees C?
2. A 50.0g sample of gold is heated, then placed in a calorimeter containing 60.0g of water. Temperature of water increases from 19.00 C to 20.00 C. The specific heat of gold is 0.130 J/g C. What was the initial temperature of the gold metal sample?

Section 7

Table 4

- The heat absorbed by one mole of a substance in melting from a solid to a liquid at a constant temperature is the **molar heat of fusion**.
- The heat lost when one mole of the liquid changes to a solid at a constant temperature is the **molar heat of solidification**.
- When a liquid evaporates, an endothermic process occurs that has a **molar heat of vaporization** (the heat absorbed when vaporized).
- When a liquid is condensed, an exothermic process occurs that has a **molar heat of condensation** (the heat lost when condensed).
- The heat change caused by dissolution of one mole of substance is the **molar heat of solution**.

Practice Problems:

1) You heat 40.0 grams of water to 100°C until it is completely vaporized. The water goes through vaporization (the heat of vaporization of water is 40.67 kJ/mol). The total heat at constant pressure is 8.07 kJ . What is the initial temperature of the water?

2) How many joules are required to heat 81.1 grams of water from -55°C to 115°C ?

10.8 Hess's Law of Heat Summation

Key Facts:

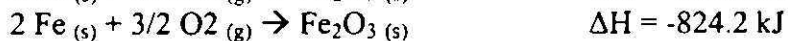
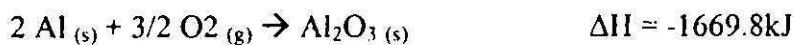
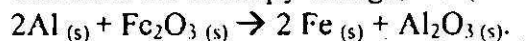
- provides way to calculate heat change
- If you add two or more thermochemical equations to give a final equation, then you can also add the heat changes to give the final heat change
- can also be used to find enthalpy changes
- when you reverse reaction you must also change the sign of ΔH
- To do the problem:
 - o Add or subtract equations
 - o Put elements into same quantities by multiplying/dividing
 - o Cross out unwanted compounds with same quantities

10.9 Standard Heats of Formation

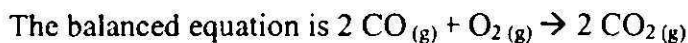
- the standard heat of formation of a compound is the change in enthalpy that accompanies the formation of one mole of a compound from its elements with all substances in their standard states at 25 degrees Celsius
- standard heat for a free element in its standard state is 0
- the ΔH for the reaction is the difference between the standard heats of formation of all the reactants and products
- $\Delta H = \Delta H^\circ_F$ of products - ΔH°_F of reactants

Sample Questions

- 1) Calculate the enthalpy change, ΔH (in kJ), for the reaction:



- 2) What is the standard heat of reaction (ΔH°) for the reaction of carbon monoxide gas with oxygen to form carbon dioxide gas?

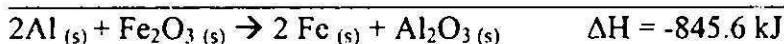
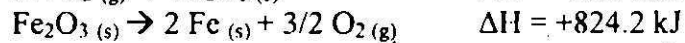
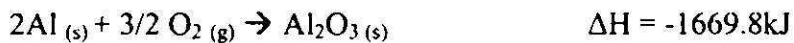


$$\Delta H^\circ_f \text{O}_{2(g)} = 0.0\text{ kJ/mol}$$

$$\Delta H^\circ_f \text{CO}_{(g)} = -110.5\text{ kJ/mol}$$

$$\Delta H^\circ_f \text{CO}_{2(g)} = -393.5\text{ kJ/mol}$$

Answer for #1



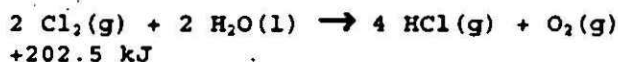
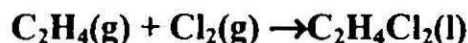
Answer for #2

$$2\text{ mol CO}_{(g)} \times \frac{-110.5\text{ kJ}}{1\text{ mol CO}_{(g)}} + 1\text{ mol O}_{2(g)} \times \frac{0.0\text{ kJ}}{1\text{ mol O}_{2(g)}} = -221.0\text{ kJ}$$

$$2\text{ mol CO}_{(g)} \times \frac{-393.5\text{ kJ}}{1\text{ mol CO}_{(g)}} = -787.0\text{ kJ}$$

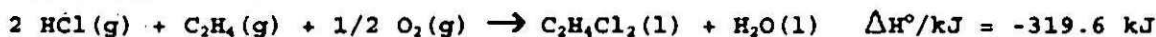
$$\Delta H^\circ = (-787.0\text{ kJ}) - (-221.0\text{ kJ}) = -566.0\text{ kJ}$$

Determine $\Delta H^\circ/\text{kJ}$ for the following reaction using the listed enthalpies of reaction:

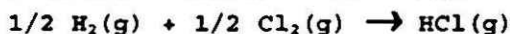


$$\Delta H^\circ/\text{kJ} =$$

$$+202.5 \text{ kJ}$$

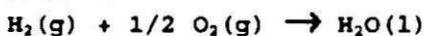


$$\Delta H^\circ/\text{kJ} = -319.6 \text{ kJ}$$



$$\Delta H^\circ/\text{kJ} = -$$

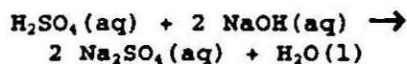
$$92.3 \text{ kJ}$$



$$\Delta H^\circ/\text{kJ} = -285.8 \text{ kJ}$$

$$-218.3$$

A volume of 50.0 mL of 0.400 M NaOH(aq) was added to 20.0 mL of 0.500 M $\text{H}_2\text{SO}_4(\text{aq})$ in a calorimeter of heat capacity 39.0 J/ $^\circ\text{K}$. The temperature of the resulting solution rose by 3.60 $^\circ\text{C}$. What is the standard enthalpy of neutralization (kJ) of $\text{H}_2\text{SO}_4(\text{aq})$ with NaOH(aq)? Assume that the heat capacity of the neutralized solution is 4.18 J. $\text{K}^{-1}\text{g}^{-1}$.



$$-119$$

How many joules are required to heat 200 grams of water from 25 degrees Celcius to 125 degrees Celcius. The heat capacity of water is 4.18 joules/g*degrees Celcius.
523.9KJ

20.0 g of gold is placed in 25.0 g of water, and the gold cools down to 101.0oC. What is the initial temperature of the gold if the initial temperature of the water is 20.00oC? Assume that gaseous particles can not receive energy from the gold.

$$2.50 \times 10^4$$

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THERMOCHEMISTRY

Practice Problems

In your notebook, solve the following problems.

SECTION 17.1 THE FLOW OF ENERGY—HEAT AND WORK

Use the three-step problem-solving approach you learned in Chapter 1.

1. How many kilojoules of energy are in a donut that contains 200.0 Calories?
2. What is the specific heat of a substance that has a mass of 25.0 g and requires 525.0 calories to raise its temperature by 15.0°C?
3. Suppose 100.0 g of H₂O(s) absorbs 1255.0 J of heat. What is the corresponding temperature change? The specific heat capacity of H₂O(s) is 2.1 J/g·°C.
4. How many joules of heat energy are required to raise the temperature of 100.0 g of aluminum by 120.0°C? The specific heat capacity of aluminum is 0.90 J/g·°C.

SECTION 17.2 MEASURING AND EXPRESSING ENTHALPY CHANGES

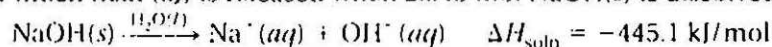
1. A student mixed 75.0 mL of water containing 0.75 mol HCl at 25°C with 75.0 mL of water containing 0.75 mol of NaOH at 25°C in a foam cup calorimeter. The temperature of the resulting solution increased to 35°C. How much heat in kilojoules was released by this reaction?

$$C_{\text{water}} = 4.18 \text{ J/g}\cdot^{\circ}\text{C}$$

2. Calculate the amount of heat evolved when 15.0 g of Ca(OH)₂ forms from the reaction of CaO(s) + H₂O(l).
- $$\text{CaO(s)} + \text{H}_2\text{O(l)} \rightarrow \text{Ca(OH)}_2\text{(s)} \quad \Delta H = -65.2 \text{ kJ}$$
3. Calculate the amount of heat produced when 52.4 g of methane, CH₄, burns in an excess of air, according to the following equation.
- $$\text{CH}_4\text{(g)} + 2\text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)} + 2\text{H}_2\text{O(l)} \quad \Delta H = -890.2 \text{ kJ}$$
4. Balance the following equation, then calculate the enthalpy change for the reaction given that the standard heat of combustion of NH₃(g) is -226 kJ/mol.
- $$\text{NH}_3\text{(g)} + \text{O}_2\text{(g)} \rightarrow \text{NO(g)} + \text{H}_2\text{O(g)}$$

SECTION 17.3 HEAT IN CHANGES OF STATE

1. Calculate the amount of heat needed to melt 35.0 g of ice at 0°C. Express your answer in kilojoules.
2. Calculate the amount of heat needed to convert 190.0 g of liquid water at 18°C to steam at 100.0°C.
3. How much heat (kJ) is released when 2.543 mol NaOH(s) is dissolved in water?

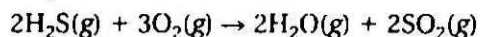


4. Calculate the amount of heat needed to convert 96 g of ice at -24°C to water at 28°C . The specific heat capacity of $\text{H}_2\text{O}(s)$ is $2.1 \text{ J/g}\cdot^{\circ}\text{C}$.

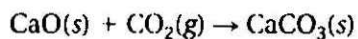
SECTION 17.4 CALCULATING HEATS OF REACTION

1. What is the standard heat of reaction for the combustion of hydrogen sulfide?

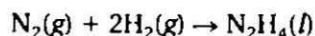
— Refer to Table 17.4 in your textbook. —



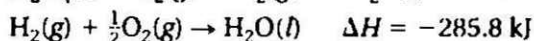
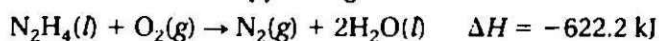
2. Calculate the enthalpy change (in kJ) for the following reaction. State whether the reaction is exothermic or endothermic. Refer to Table 17.4 in your textbook.



3. What is the enthalpy change for the formation of hydrazine, $\text{N}_2\text{H}_4(l)$, from its elements?



Use the following reactions and enthalpy changes:



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Chapter 17: Thermochemistry

Answer these while you read and answer the in-text questions:

1. How is temperature different than heat?
2. Use the terms system, surroundings, and universe to describe the flow of heat in endothermic and exothermic processes.
3. Compare and contrast heat capacity and specific heat.
4. Do # 4 on page 510.
5. Is it safe to say that heat equals enthalpy?
6. How is water used to measure the heat capacity in a calorimeter?